2.0 SITE DESCRIPTION, OBJECTIVES, AND PROCEDURES

A description of the demonstration site, as well as objectives and procedures for the flow sensor evaluation, are described in the following sections. Specifically, Section 2.1 provides a demonstration site description; Section 2.2 describes the objectives of the evaluation; Section 2.3 describes the field and analytical methods including placement and installation of groundwater velocity sensors, design of the evaluation, data presentation, and data analysis; Section 2.4 presents the quality assurance and quality control (QA/QC) procedures; and Section 2.5 presents the modifications to the Technology Evaluation Plan that were implemented during the technology evaluation.

2.1 DEMONSTRATION SITE DESCRIPTION

This section provides information on site conditions, including the site location, history, geology, hydrogeology, and soil and groundwater contamination at CCAS Facility 1381. This section also provides a summary of the site hydrogeological conceptual model.

2.1.1 Site Location

CCAS is on Canaveral Peninsula, which is the easternmost portion of Merritt Island, a barrier island in Brevard County on the Atlantic coast of Florida (Figure 1). The main complex of CCAS consists of assembly and launch facilities for missiles and space vehicles and occupies 25 square miles. The property is bounded by the Atlantic Ocean to the east and the Banana River to the west. The southern boundary is an artificial shipping canal; the John F. Kennedy Space Center (KSC) adjoins CCAS to the north. Facility 1381 is located in the east-central portion of CCAS. A site map is included as Figure 2.

2.1.2 Site History

Since it was established in 1950, CCAS has been a proving ground for research, development, and testing of the country's military missile programs. Seventy-three miles of paved roads at CCAS connect the various launch and support facilities with the centralized industrial area. The primary industrial activities at CCAS support missile launches from CCAS and spacecraft launches from KSC. CCAS also provides support for submarine port activities (Parsons 1999b).

Facility 1381 has been used for several operations since it was built in 1958. For the 10 years after construction, Facility 1381 was used as the Guidance Azimuth Transfer Building. Aerial photographs from that time indicate numerous drums and tanker trucks at the facility. Verbal reports indicate that the tanker trucks were used for dumping waste solvents in the forest that surrounds the facility. In 1968, the site became the In-Place Precision Cleaning Laboratory. Specific activities included cleaning metal components in acid and solvent dip tanks, resulting in the generation of approximately 3,300 gallons of waste trichloroethene (TCE) per year. In 1977, the facility became known as the Ordnance Support Facility, and its name has remained unchanged to the present time (Parsons 1999b).

2.1.3 Regional and Site Geology

This section discusses the regional and site geology near CCAS and Facility 1381.

2.1.3.1 Regional Geology

Florida constitutes the southeast portion of the Atlantic Coastal Plain physiographic province of the southeastern United States. The Coastal Plain is a thick sequence of unconsolidated to semiconsolidated sedimentary rocks that range from Jurassic to Holocene in age. The configuration of rocks in the Coastal Plain is a tilted wedge that slopes and thickens seaward toward the Atlantic Ocean and the Gulf of Mexico.

In Florida, the sequence of sedimentary rocks that make up the Coastal Plain is referred to as the Florida Platform. The Florida Platform rocks were deposited on top of an eroded surface of a crystalline rock complex, which is known collectively as the Florida basement rocks. The Florida basement rocks, consisting of low-grade metamorphics and igneous intrusives, occur several thousand feet below the land surface and are Precambrian, Paleozoic, and Mesozoic in age.

The base of the sedimentary rocks in the Florida Platform is made up of a thick, primarily carbonate sequence deposited from the Jurassic through the Paleocene. Starting in the Miocene and continuing through the Holocene, siliciclastic sedimentation became more dominant.

The east coast of Florida is bounded by a continental shelf that is moderately broad and slopes gently to the north but becomes both narrower and steeper to the south, toward Cape Canaveral. Cape Canaveral is a prominent feature, a large cuspate foreland or promontory that projects 13 miles seaward of the main coastal trend and strongly influences the orientation and sedimentation patterns along at least 80 miles of Florida's east coast. Cape Canaveral itself may have been formed by converging littoral transport along the coast (Davis 1997).

2.1.3.2 Site Geology

CCAS is situated on Canaveral Peninsula, which is on the east side of Merritt Island, a barrier island in Brevard County on the Atlantic coast of Florida. Facility 1381 is located in the central portion of CCAS. The topography at Facility 1381 is relatively flat, with ground elevations ranging from approximately 5 to 10 feet above mean sea level (msl) (Parsons 1999a). The topography consists of long, northeast-southwest trending, low rises that are most likely depositional features associated with accretion of the barrier island. Vertical relief in the area is limited to shoulders of drainage canals that slope from the ground surface to the canal bed. Drainage canals are located 200 feet southwest (Landfill Canal) and 2,500 feet north (Northern Drainage Canal) of the GCW; both flow westward toward the Banana River.

The site geology is presented in cross-section A-A', which is shown as Figure 3. Based on previous work at the site conducted by Parsons (2000), the geology at Facility 1381 consists of unconsolidated sediments to a depth of at least 60 feet bgs. The upper 15 feet consists of poorly sorted, dominantly coarse shell material and coarse to medium sand.

The average grain size of the sand fraction decreases and the silt and clay content increases from depths of 35 feet to approximately 50 feet below ground surface (bgs). A 5-foot-thick unit of fine to very fine-grained sand and silt occurs from 35 to 40 feet bgs. Shell fragments and coarse sand occur with varying amounts of clay from approximately 40 to 50 feet bgs.

A layer of firm clay, which may be continuous across the site, has been encountered at a depth of 50 feet bgs.

2.1.4 Regional and Site Hydrogeology

The regional and site hydrogeology are discussed in the following subsections.

2.1.4.1 Regional Hydrogeology

Regional hydrostratigrapic units that occur near Cape Canaveral are presented in Figure 4 and are described below.

Surficial Aquifer. The uppermost water-bearing unit near the site is the surficial aquifer, which is unconfined and consists primarily of unconsolidated materials. The surficial aquifer system is a shallow, nonartesian aquifer, which occurs over much of eastern Florida but is not an important source of groundwater because better supplies are generally available from other aquifers. The extent of the surficial aquifer is shown in Figure 5.

The surficial aquifer system extends to a depth of approximately 50 to 60 feet bgs near CCAS. The surficial aquifer is described as consisting of fine to medium quartz sand that contains varying amounts of silt, clay, and loose shells that are post-Miocene in age. In coastal areas, such as at CCAS, the surficial aquifer may also consist of partially cemented shell beds or coquina. The depth of the water table in the surficial aquifer ranges from at or near the land surface in low-lying areas to tens of feet below the land surface in areas of higher elevations.

The most important function of the surficial aquifer is to store water, some of which recharges the underlying Floridan aquifer. The surficial aquifer is little used as a source of drinking water since its permeability is low, resulting in relatively limited yield to wells, when compared with the Floridan aquifer system. The surficial aquifer is used to supply potable drinking water only in coastal areas where the underlying Floridan aquifer may be brackish (Miller 1986).

The sands of the surficial aquifer generally grade into less permeable clayey or silty sands or low-permeability carbonate rocks at depths of usually less than 75 feet below the land surface. These rocks act as a confining unit for limestones that compose the underlying Floridan aquifer system. This upper confining unit of the Floridan aquifer system, as it is known, is generally composed of the middle Miocene-aged Hawthorn Formation, low-permeability rocks that in most places separate the Floridan aquifer from the surficial aquifer.

Floridan Aquifer. The Floridan aquifer system is a nearly vertically continuous, very thick sequence of generally highly permeable carbonate rocks. The degree of hydraulic connection of units that make up the Floridan aquifer depends primarily on the texture and mineralogy of the rocks that constitute the system (Miller 1986). The Floridan aquifer system is composed of sequences of limestone and dolomitic limestone.

The top of the Floridan Aquifer is defined as the first occurrence of vertically persistent, permeable, consolidated carbonate rocks. Rocks at the top of the Floridan aquifer at CCAS occur at an elevation of approximately 150.0 feet below msl or at a depth of 160 feet bgs. The top unit of the Floridan aquifer at CCAS is composed of the Ocala Limestone of late Eocene age, and the Floridan aquifer system ranges in thickness from 2,600 to 2,700 feet. The base of the Floridan aquifer system is defined as the first occurrence of anhydrite or presence of a gradational contact of generally permeable carbonate to much less permeable gypsiferous and anhydritic rocks. These low-permeability rocks, known as the lower confining unit of the Floridan aquifer system, everywhere underlie the Floridan. The transmissivity of the Upper Floridan aquifer that underlies CCAS is estimated to be 50,000 to 100,000 square ft/day (Miller 1986).

Geologic formations that make up the Floridan aquifer in east-central Florida are, from top to bottom, the Suwanee Limestone (where present), Eocene in age; the Ocala Limestone (where present); the Avon Park Formation; and, in some areas, all or part of the Oldsmar Formation. Paleocene rocks of the Cedar Keys Formation usually are recognized as forming the base of the Floridan aquifer system, except in areas where the upper part of the Cedar Keys Formation is permeable (Tibbals 1990).

2.1.4.2 Site Hydrogeology

The shallow aquifer zone at Facility 1381 is part of the surficial aquifer, which, as described previously, is a regionally unconfined water table aquifer. The water table at CCAS generally occurs at depths ranging from 3 to 15 feet bgs. The water table occurred at approximately 8 feet bgs near the area where the groundwater circulation well was installed.

Flow of shallow groundwater at CCAS is controlled by an engineered drainage system consisting of a series of man-made canals, which were installed to reclaim land by lowering the water table. Surface water at the site drains through the canals and discharges into the Banana River, which is located west of CCAS. Closest to Facility 1381 is Landfill Canal, which is located 200 feet southwest; the Northern Drainage Canal is located about 2,500 feet due north of Facility 1381.

The canals strongly influence flow of shallow groundwater at the site. A groundwater divide is indicated in the vicinity of the GCW, as evidenced by groundwater flow to the southwest toward Landfill Canal, as well as to the northeast in the direction of the Northern Drainage Canal. Surface water elevations measured in the canals are lower than adjacent shallow groundwater elevations, suggesting groundwater discharge to the canals (Parsons 2000).

The upper part of the surficial aquifer at Facility 1381 has been delineated into shallow and deep aquifer zones for this evaluation. The shallow aquifer zone is defined as the upper saturated portion of the aquifer, from the water table to the contact of the coarse-grained shell and coarse to medium grained sand unit that occurs approximately 15 feet bgs. The shallow aquifer zone is approximately 8 feet thick. The deep aquifer zone is made up of medium to fine sand units, which occur at depths of 15 to 30 feet bgs. The shallow and deep aquifer zones are depicted on Figure 3, cross-section A-A'.

The hydraulic conductivity of the surficial aquifer at Facility 1381 was previously measured using rising head slug tests at a monitoring well pair, 1381MWS09 (screened 7.5 to 12.5 feet bgs) and 1381MWI09 (screened 30 to 35 feet bgs), located 55 feet southeast of the GCW. The calculated hydraulic conductivity values are 11.6 ft/day for the shallow well and 0.4 ft/day for the deep well.

Slug testing in piezometers near the GCW yielded hydraulic conductivity values of 17.8 to 24.2 ft/day in piezometer 4PZS (screened 6.5 to 9.5 feet bgs) in the shallow aquifer zone and 0.1 to 0.2 ft/day in piezometers 2PZD (screened 21.3 to 24.6 feet bgs) and 6PZD (screened 22.7 to 26 feet bgs) in the deep aquifer zone. The groundwater velocity in the shallow aquifer zone under natural flow conditions is estimated at 0.21 ft/day (Parsons 2000).

Values for hydraulic conductivity obtained from aquifer testing conducted in September 2000 are presented in Appendix A, the Hydrogeological Investigation Report. Based on the pumping test data, the hydraulic conductivity of the estimated saturated upper portion of the aquifer (42 feet thick) ranges from 43 to 53 ft/day.

2.1.5 Site Contamination

Contamination in soil and groundwater at Facility 1381 has been attributed to historical waste disposal practices. A plume of contaminants in groundwater, consisting primarily of TCE and associated degradation products including cis-1,2-dichloroethene and vinyl chloride, has been detected at the site. The plume is 110 acres in areal extent and is 2,500 feet long. The axis of the plume is elongated to the north-northeast.

The maximum concentration of TCE detected to date in the suspected source area is 342,000 micrograms per liter (µg/L) (Parsons 1999b). Concentrations of TCE measured in samples from the source area have been lower during more recent sampling rounds.

2.2 OBJECTIVES OF EVALUATION

The SITE evaluation was designed to address primary and secondary objectives selected for the GCW technology. These objectives were selected to provide potential users of the GCW technology with technical information on the groundwater circulation cell established by the treatment system. One primary and four secondary objectives were selected for the SITE evaluation of the GCW technology and are listed below:

<u>Primary Objective:</u>

P1 Evaluate the flow sensor's ability to detect the horizontal extent of the GCW groundwater circulation cell based on a change in the groundwater velocity criterion of 0.1 foot per day (0.03 meter per day)

<u>Secondary Objectives:</u>

S1 Evaluate the reproducibility of the groundwater velocity sensor data

S2 Evaluate the three-dimensional groundwater flow surrounding the GCW

S3 Document the operating parameters of the GCW.

S4 Document the hydrogeologic characteristics at the treatment site.

The objectives were evaluated by collecting in situ groundwater sensor data and conducting a series of aquifer hydraulic tests. Data were collected and analyzed using the methods and procedures summarized in Section 2.3 to meet the objectives of the evaluation.

2.3 METHODOLOGY OF EVALUATION

This section describes the procedures used to collect and analyze data from the groundwater flow sensors.

2.3.1 Placement and Installation of Groundwater Flow Sensors

The strategy for placement and installation procedures for the groundwater flow sensors is described in the following subsections.

2.3.1.1 Placement of Sensors

Seven groundwater flow sensors manufactured by HydroTechnics were installed during the week of June 24, 2000. The flow sensors were installed in two separate clusters southeast of and in two separate clusters southwest of the GCW.

Data collected from the flow sensors were used to evaluate both the horizontal extent of recirculation and the overall three-dimensional groundwater flow pattern that surrounds the GCW. Modeling of the circulation cell performed by the Oregon Graduate Research Institute was used to predict the horizontal extent of the circulation cell and to select the locations of the flow sensors. The modeling predicted that groundwater in the upper portion of the treatment zone would flow radially away from the GCW, and that groundwater in the lower portion of the treatment zone would flow radially toward the GCW. The results of modeling were also used to show that flow velocities surrounding the GCW would decrease with distance from the GCW. The modeling results indicated that the extent of circulation at velocities that exceeded 0.05 ft/day appeared to be limited to a radial distance of 10 feet from the GCW. In addition, induced groundwater flow velocities near the GCW were predicted to exceed 2.0 ft/day at a distance of 5 feet from the GCW. Based on the modeling results, the most appropriate zone for installation of flow sensors is between 5 feet and 10 feet from the GCW.

The velocity range of groundwater flow that can be accurately measured by the groundwater flow sensors is between 0.01 and 2.0 ft/day, based on the manufacturer's specifications. Based on this criterion and the results of modeling for the GCW, two of the flow sensor clusters were installed 7.5 feet from the GCW, and two of the flow sensor clusters were installed 13 to 15 feet from the GCW. This strategy for placement of the sensors took into account the measurement range of the sensors of 0.01 to 2.0 ft/day to ensure that changes in the velocity of groundwater flow can be accurately measured.

The sensors were installed in relation to the assumed hydraulic gradient, which was determined to be to the southwest. Three flow sensors were placed to the southwest (assumed downgradient) of the GCW. Another four flow sensors were placed to the southeast (assumed cross gradient) of the GCW (Figure 6).

2.3.1.2 Installation of Flow Sensors

The sensors were installed using a hollow-stem auger drilling rig equipped with 4.25-inch-inner-diameter augers. The sensor was then lowered through the inner annulus of the drill pipe by attaching it to a 2-inch-diameter schedule 40 PVC well casing. The well casing was used to house the sensor cables in addition to providing a platform that enabled the field crew to lower the sensors into the borehole. After the sensor was seated at the bottom of the boring, the auger flights were retracted, allowing the saturated unconsolidated aquifer matrix to collapse around the flow sensor.

2.3.2 Methodology for Evaluation of Data from Flow Sensors

Evaluation of the flow sensors consists of using the data collected to assess the presence of a three-dimensional groundwater flow regime or circulation cell. The circulation cell is induced when the GCW is in recirculation mode. For this evaluation, evidence for the existence and the extent of the circulation cell was as follows:

(1) Increases in horizontal groundwater Darcy velocities (hydraulic conductivity times hydraulic gradient) in excess of 0.1 ft/day.

(2) Changes in vertical groundwater Darcy velocities and the vertical hydraulic gradient.

(3) Changes in direction of groundwater flow such that flow is away from the upper screen of the GCW in the shallow aquifer zone and toward the lower screen of the GCW in the deep aquifer zone.

The evaluation was designed to assess changes in the velocity of groundwater flow (magnitude and direction) measured by the flow sensors.

Data from the flow sensors were presented in hydrographs as horizontal and vertical velocity versus time, plotted in map view to show the horizontal component of velocity and direction, and plotted in cross-section view showing resulting groundwater velocities and directions of groundwater flow. In addition, the data on groundwater velocity that represent each operational period were tabulated.

The groundwater flow sensors were installed in linear arrays at varying distances and depths from the GCW in order to achieve the primary objectives defined in Section 2.2. Velocities and directions of groundwater flow within the circulation cell of the GCW were measured using seven in situ groundwater flow sensors in each cluster. The horizontal change in velocity was calculated by subtracting the measured flow velocity. The changes in velocity of flow were calculated for each operational mode using the data set that began when steady-state flow conditions had been established. Locations where changes in the velocity of flow were equal to or greater than 0.1 ft/day were considered to be within the extent of the circulation cell created by the GCW.

The three-dimensional groundwater flow that surrounds the GCW was evaluated to identify overall changes in direction of groundwater flow and velocity attributed to the GCW. The three-dimensional groundwater flow pattern was depicted qualitatively using hydrographs, horizontal flow vector maps, and resulting flow velocity projected onto cross-sections. The three-dimensional groundwater flow was depicted separately for each operating condition.

The following process control data collected by AFCEE during operation of the GCW evaluation were used to document the operating parameters of the GCW: (1) water pumping rate, (2) duration of system operation, and (3) description of any system shutdowns.

Hydrogeologic data collected during previous investigations at Facility 1381 were reviewed to develop a site hydrogeologic conceptual model. A series of aquifer tests were also conducted to evaluate the hydraulic parameters in the shallow aquifer zone such as hydraulic conductivity (K), transmissivity (T), storativity (S), and specific yield (S_y). These data were used in combination with data from the flow sensors to assess groundwater flow patterns within the treatment zones.

2.4 QUALITY ASSURANCE AND QUALITY CONTROL PROGRAM

This section discusses QC measures that were used during installation and operation of the flow sensors.

2.4.1 Calibration Procedures for Flow Sensors

All flow sensors undergo a two-step calibration process. The first calibration step occurs at the factory and involves certifying that all thermistors measure temperature differences as small as 0.01 C in a water bath and creating a signal signature, or calibration file. The second calibration step occurs in the field, involving mathematically correcting for recorded lithology-induced thermal variations. The end result is a probe that records the thermal distribution over its surface independent of lithology and as measured against a known standard

2.4.2 Installation Procedures for Flow Sensors

QA/QC procedures implemented during installation of the sensors ensured that the exact location, depth, and orientation of each sensor were recorded, and that the sensors were operating properly after they were installed. The procedure for installation included recording the number designated by the factory from each sensor and labeling each sensor with an appropriate EPA identification number. Each EPA identification number included the project name, the work assignment number, the number designated by the factory, the relationship to the GCW, and a two-digit consecutive number.

A reference line on each sensor was translated to the surface indicating its orientation. The sensors were attached to the top of the PVC casing. The line was marked on the side of the PVC casing so that the orientation of the sensor would be identified at the ground surface. When installation was complete, the orientation of the sensor was verified using a compass that had been corrected for declination. HydroTechnics requires the orientation of the sensor as an input to the data processing software. After the sensors were installed and oriented, the electrical resistance of each flow sensor was checked to make sure that it was working properly. The GCW and the locations of the flow sensors were surveyed and the horizontal coordinates were used to calculate the exact distances of the flow sensors from the GCW.

2.4.3 Data Processing Procedures

The probes generate raw minivolt data that HTFLOW© software interprets. QA/QC procedures used in processing raw millivolt data used the two reference resisters built into each sensor. The two reference resisters are fixed and read constant values regardless of the temperature or position of the sensor in the subsurface. The data loggers collect and store readings from the reference resisters as part of the main data file. The reference resisters serve as a check to ensure that data being collected are accurate and are not subject to any electrical interferences.

2.5 MODIFICATIONS TO THE TECHNOLOGY EVALUATION PLAN

The TEP (Tetra Tech 2000) specified that the flow sensors would be installed near the GCW and in relation to the natural flow gradient. Two groups of flow sensors, consisting of deep and shallow clusters, were to be installed downgradient of the GCW, and two clusters were to be installed cross-gradient from the GCW. The sensors were installed assuming a natural flow gradient to the southwest. Groundwater elevation data collected in 2000, however, suggest that the horizontal hydraulic gradient is very low and that the direction of groundwater flow near the GCW varies. Evidence also indicates that a groundwater flow divide is present near the GCW. Because a constant hydraulic gradient is absent, the relationship of the locations of the flow sensors to the natural direction of groundwater flow cannot be established.

The flow sensors were installed at depths that varied from the plan. The deep sensors were installed 1 to 2 feet shallower than was planned because of subsurface conditions encountered during their installation. Soil samples collected from the deeper portion of the aquifer showed an increase in fine-grained materials. The sensors were installed in the shallower, more permeable portion of the aquifer to ensure flow around the sensor would be measurable.

To evaluate the flow in the upper screened interval, it was therefore decided in the field to install the shallow sensors at a depth of approximately 1 foot (0.3 meters) below the existing groundwater surface. The shallow sensors were installed at a lower depth because the groundwater level at the site was lower than was anticipated. Florida was experiencing a drought and static water levels were several feet lower than had been reported in previous site investigations. The shallow flow sensors were installed with less than manufacturer recommended submergence because initial modeling results indicated that there would not be measurable flow deeper than 6.6 feet (2 meters) into the aquifer 6.6 feet (2 meters) radial distance from GCW. With effort the manufacturer was able to interpret shallow sensor data.

In most cases, the radial distances of the flow sensors from the GCW were within 0.25 feet of those specified in the plan. The clusters of flow sensors were installed along a line such that the deep flow sensors were farther away from the GCW than were the shallow flow sensors. As a result, the following exceptions were noted with respect to installation distances of the flow sensors. Deep flow sensor C02 was installed 1.5 feet farther away from the GCW than was specified in the plan. Deep flow sensor D02 was installed approximately 1.75 feet farther from the GCW than was specified in the plan. Shallow flow sensor C03 was installed 0.5 feet closer to the GCW than was specified in the plan.

While the technical data collection performed during the demonstration was generally consistent with the requirements of the TEP, except as noted above, the wording of the primary objective and first secondary objective were slightly revised for the purposes of clarity in reporting the results of the demonstration. The TEP reports the primary objective as to evaluate the horizontal extent of the groundwater circulation cell. This TER reports the primary objective more accurately as to evaluate the flow sensor's ability to detect the horizontal extent of the groundwater circulation cell. The first secondary objective was reworded to more accurately reflect the objective to evaluate the reproducibility of the groundwater velocity data obtained from the flow sensors; rather than the original wording, which was to evaluate the precision of the sensors.